

Mooring Force Analysis Methods

...with Application to Breakaways
Caused by Passing Vessels

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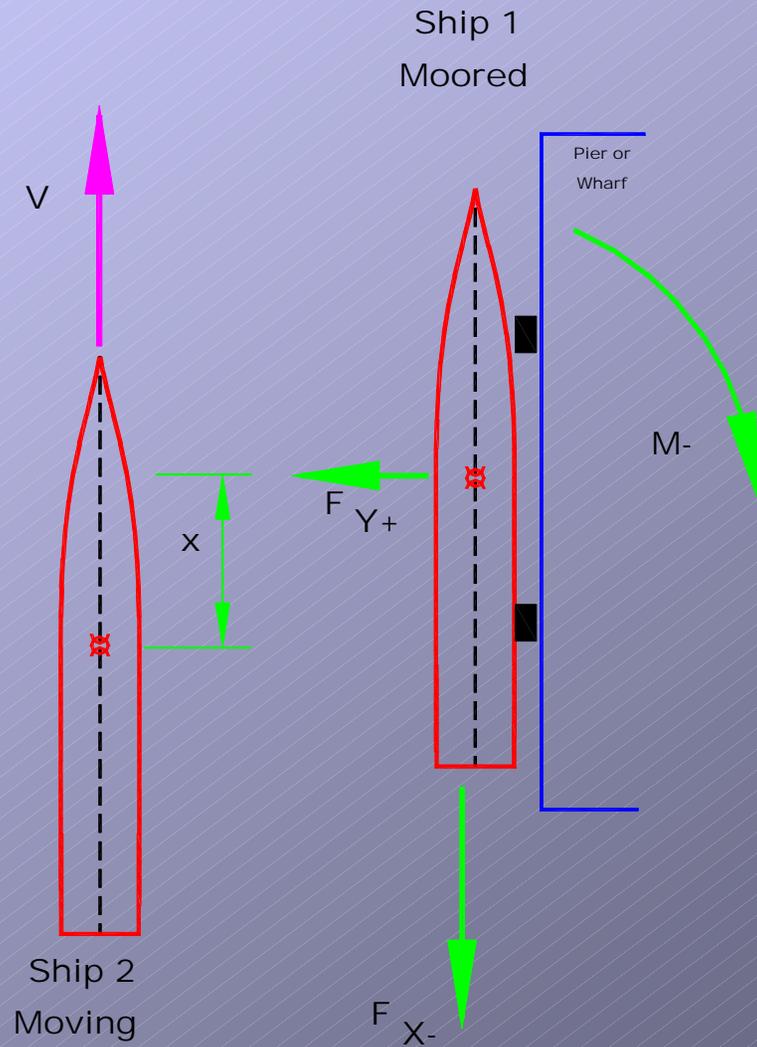
U.S. Naval Academy

Annapolis, MD

Overview

- Purpose
- Background
- USCG MC Incident Data
- Findings from Actual Cases
- Discussion
- Conclusions
- Acknowledgements

The Phenomenon



Why Develop & Study Mooring Forces Methods?

- Design of Navigation Channels
- Reducing Marine Casualty Incidents (and Consequences)
 - Property Damage – Ship & Pier
 - Pollution
 - Injuries/Deaths



Motivation and Purpose of Project

- Deep-Draft navigation channel congestion
 - Traffic
 - Blockage
 - Ship berths in close proximity to transiting vessels
- Tasked to investigate occurrences of vessel mooring breakaways due to passing vessels
 - Frequency; Locations
 - Characteristics & preliminary analysis of events

Mooring Force Analysis Methods

- Numerical
- Analytical
- Physical
 - Experimental / Model-Scale
 - Full-Scale
 - Evidentiary or “Forensic”

Background

● Literature Review

■ Navy

- **MIL- HDBK 1026/4**: Mooring Design Handbook (repl. NAVFAC DM 26.4)
- **MIL-HDBK 1025/1**: Piers and Wharves
- **DM 26.6**: Mooring Design Physical and Empirical Data
- **TR-6005-OCN**: 'EMOOR' - A Planning/Preliminary Design Tool for Evaluating Ship Moorings at Piers and Wharves

■ USACE

- **EM 1110-2-1100 (Part II)**:
CEM Harbor Hydrodynamics

● Literature Review (cont'd)

■ Essential Reference

- *Guidelines and Recommendations for the Safe Mooring of Large Ships at Piers and Sea Islands*, Oil Companies International Marine Forum (OCIMF)
- Proceedings, North Atlantic Treaty Organization (NATO) Advanced Study Institute on Analytical Treatment of Problems of Berthing and Mooring Ships (Lisbon, Portugal, 1965), Published by ASCE 1970
- NATO-ASI Advances in Berthing and Mooring of Ships and Offshore Structures, Trondheim, Norway, 1987, E. Bratteland, ed.
- *Design of Marine Facilities*, J. Gaythwaite, 1990
- *Port Engineering*, P. Bruun
- *Handbook of Port & Harbor Engineering*, G. Tsinker
- Seelig (2001), Flory (2001), Lean and Price (1977), King (1977) Wang(1975), Muga and Fang (1975), Remery (1974)

● Mooring Analysis Software

- Navy

- E-MOOR, FIXMOOR, PASS-MOOR

- Commercial

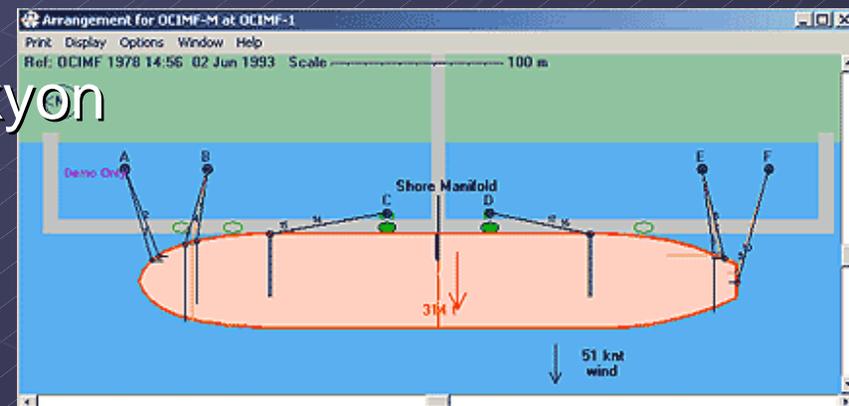
- Ship-Generated Hydrodynamics (SGH) – PI Engineering → MOSES

- OPTIMOOR - Tension Technology

- AQWA - WS Atkins

- SHIP-MOORINGS – Alkyon

- Others



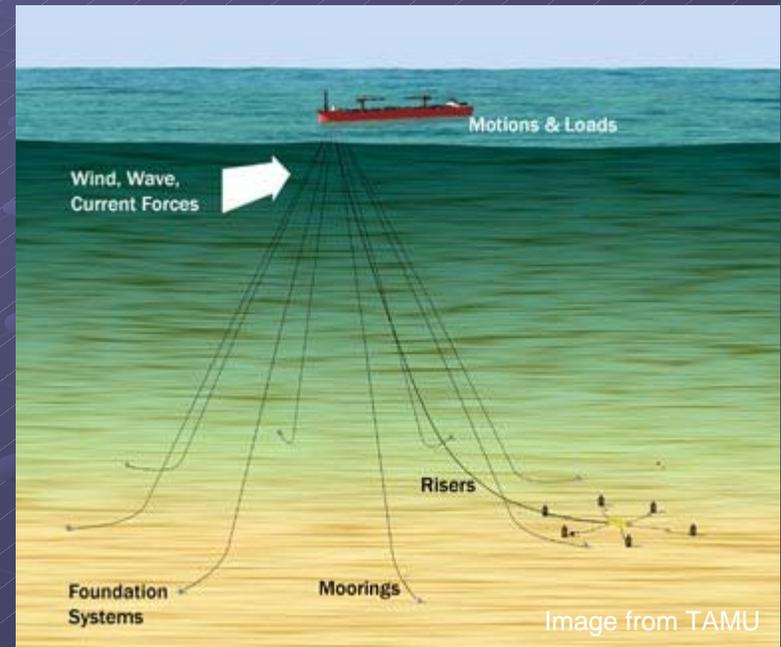
Mooring Line Research

● Deepwater Mooring Analysis

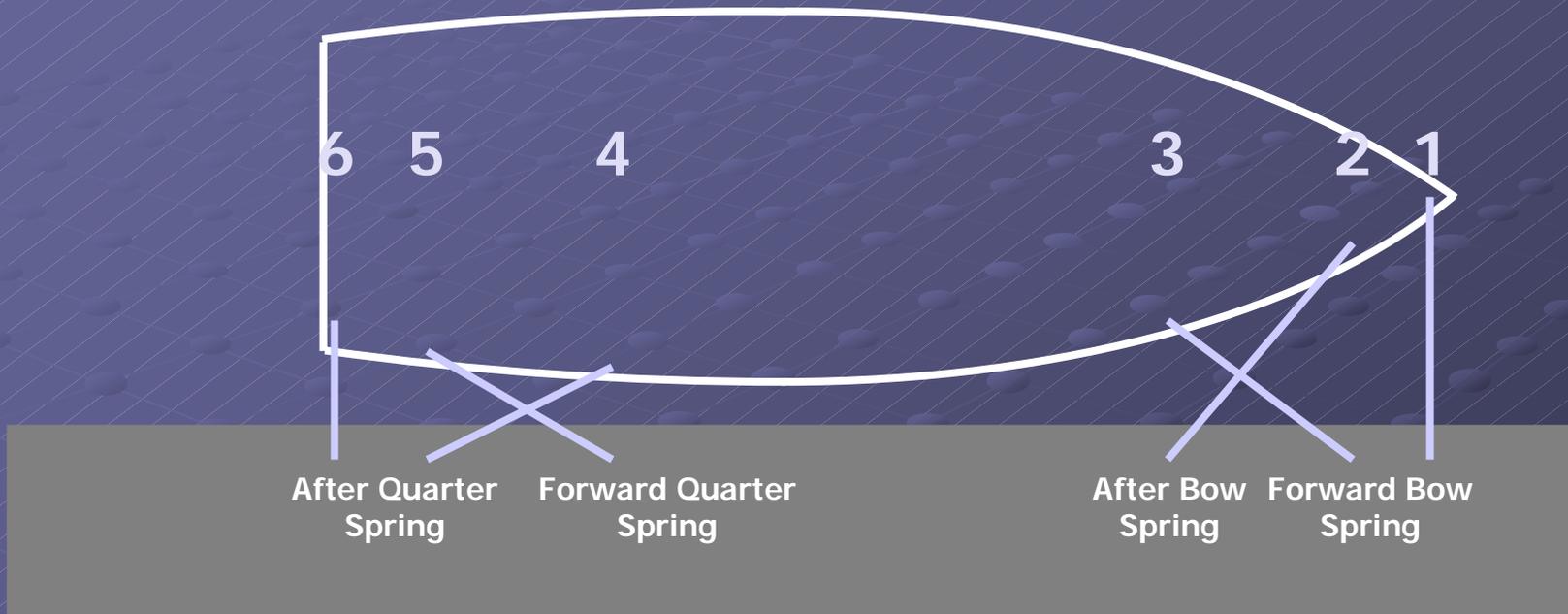
- Many Studies
- TAMU; MARIN
- Catenary; TLP

● Pierside Mooring Line Dynamics

- Not much in literature
- Geometry much more complex
- Usually based on linear or non-linear elastic theory



Mooring Line Arrangements



Stern
Line

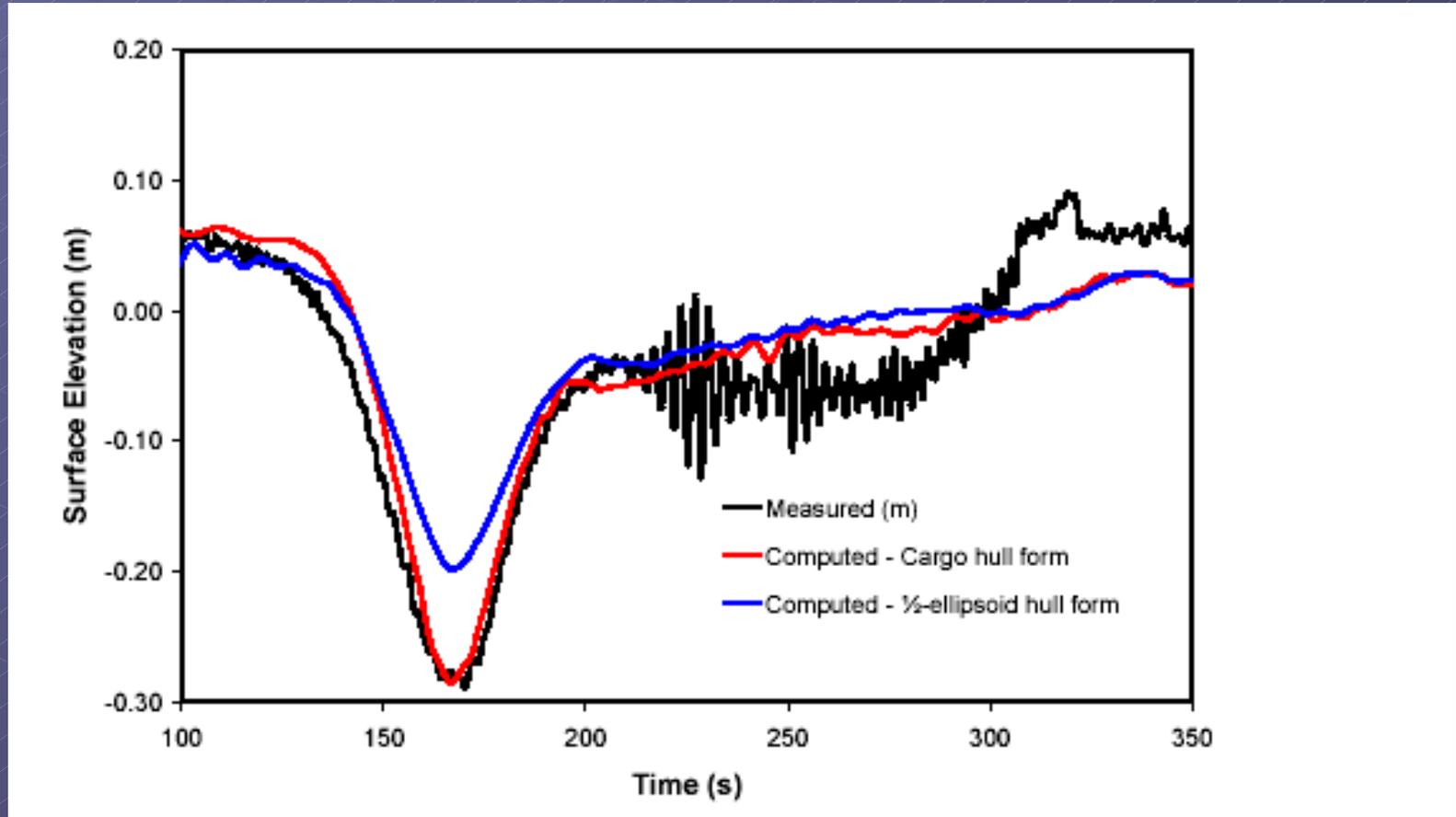
Spring Lines

Bow
Line

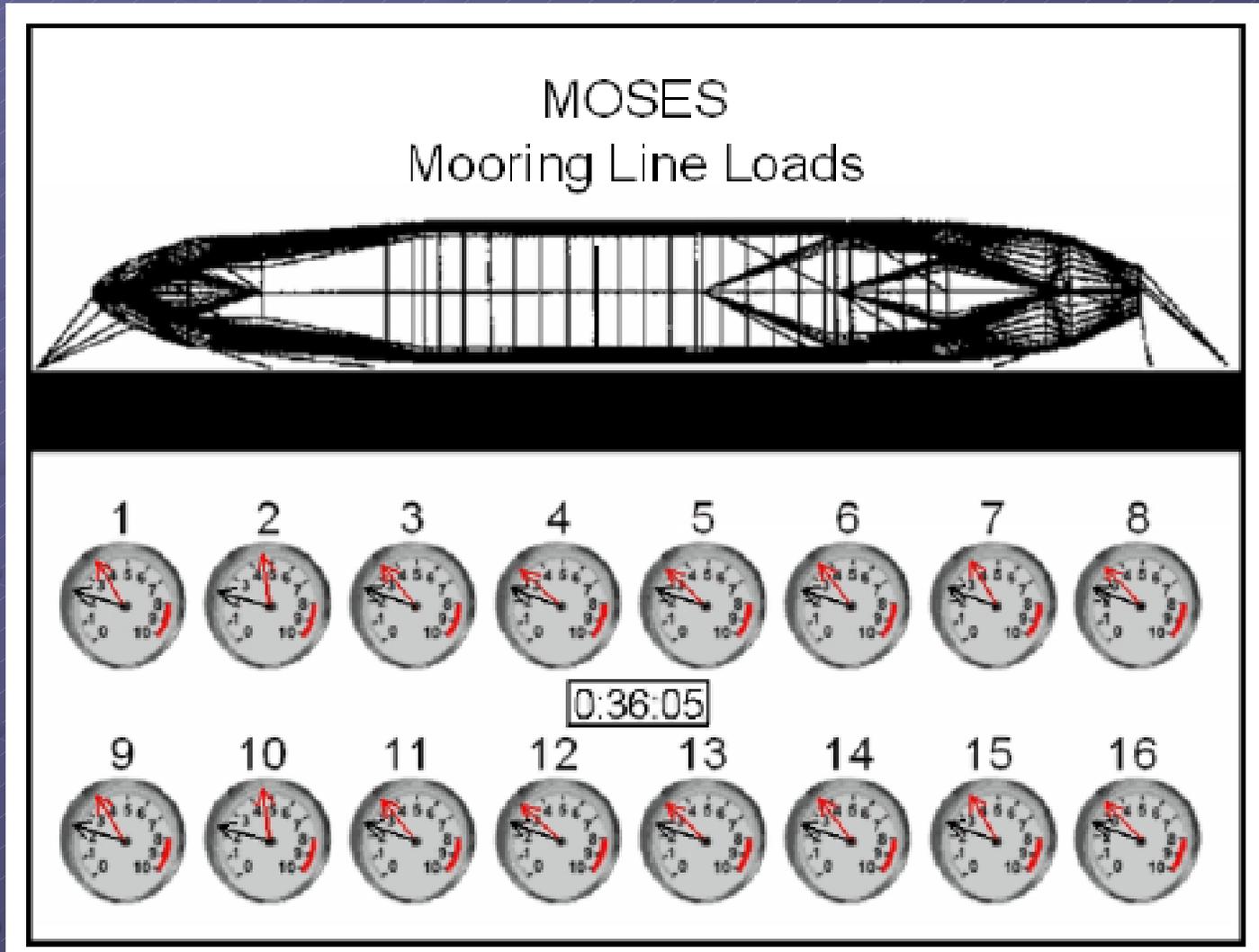
● OCIMF Guidelines ...

- Balanced load distribution
- Loads < 55% MBL
- Line types
- Others

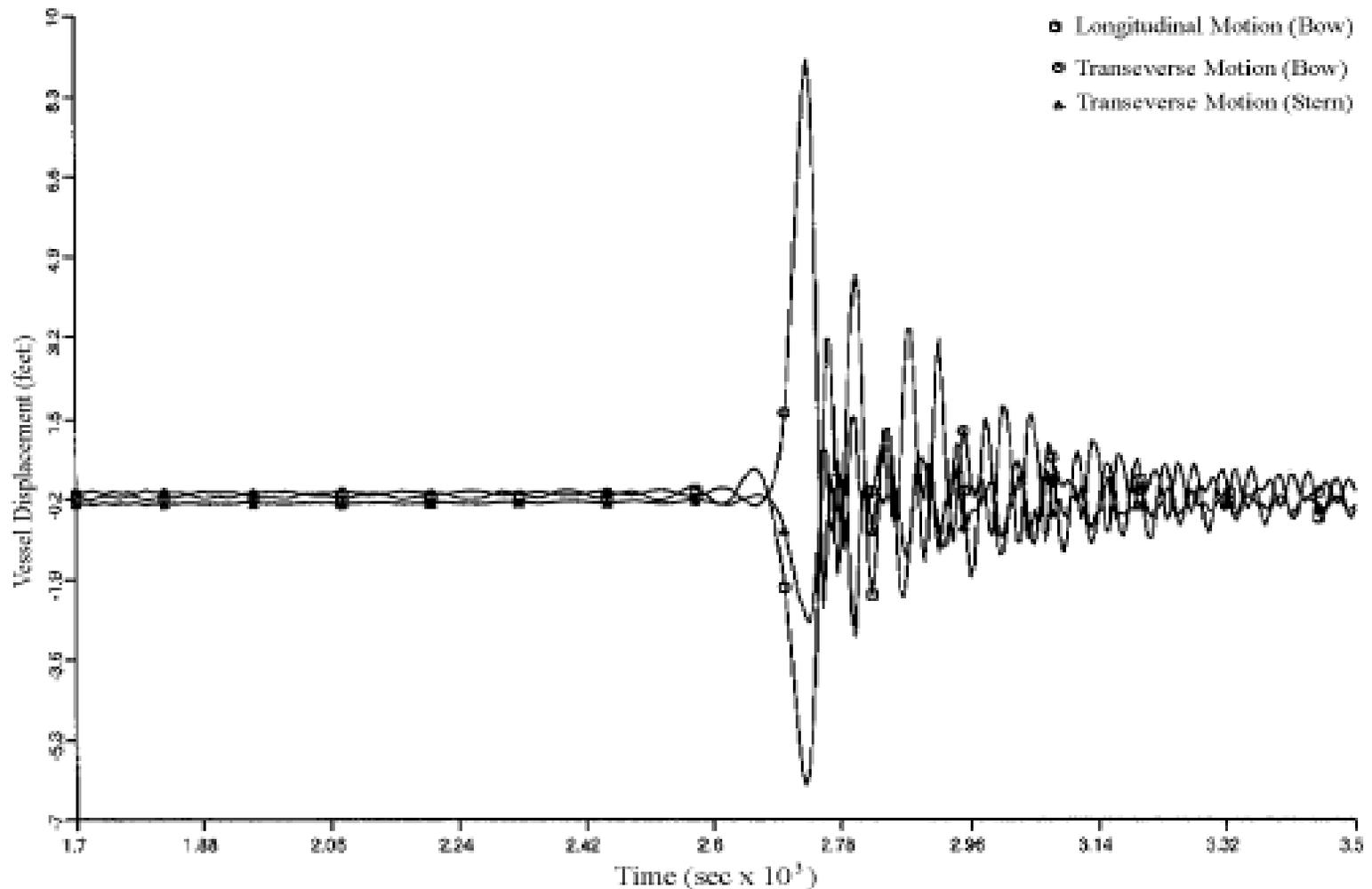
Typical Mooring Force Analysis: Begin w/ Hydrodynamic Model (Example Shown: SGH)



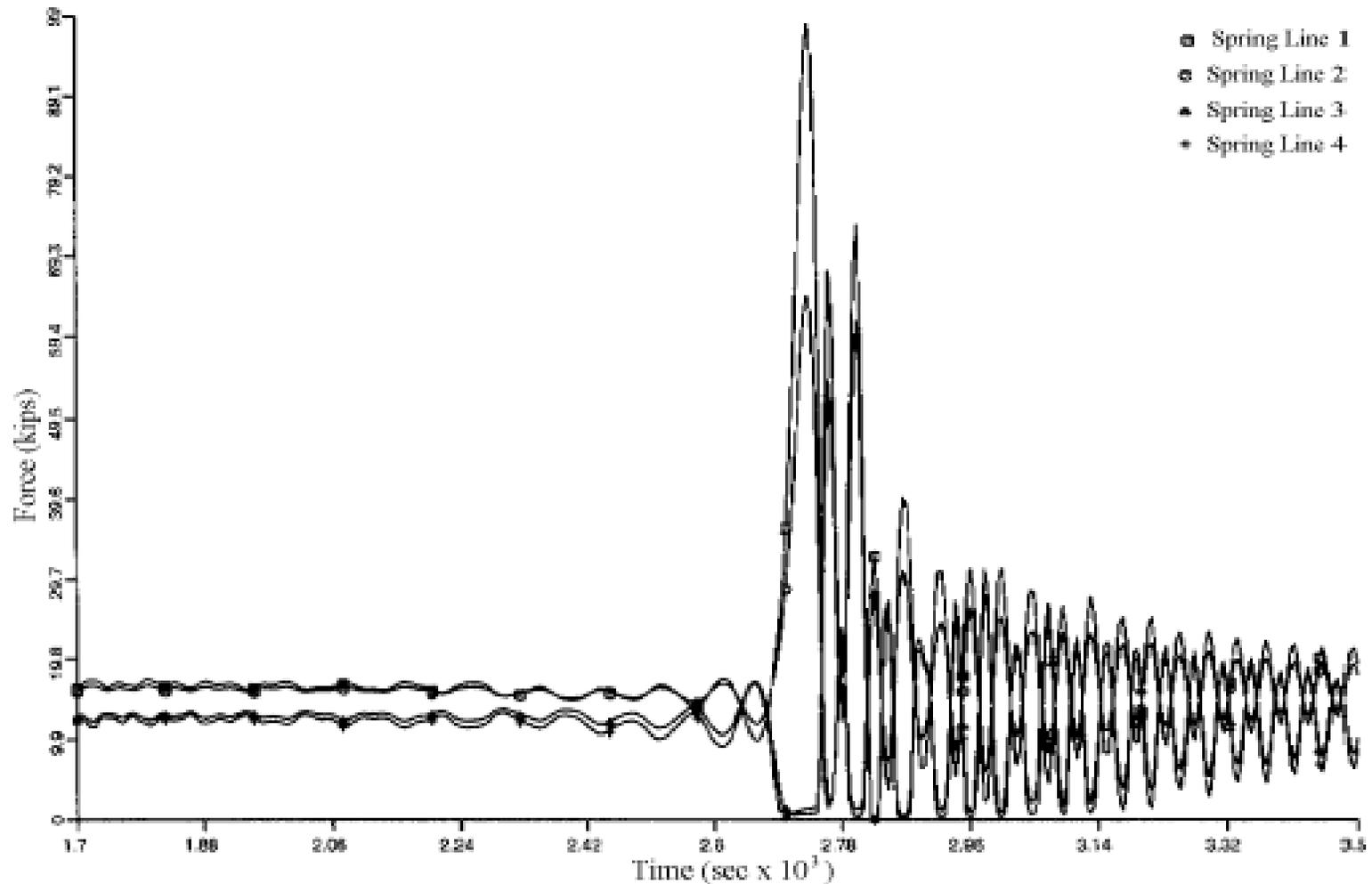
... Mooring Line Analysis



... Determine Vessel Motions



...and Mooring Line Loads



Approach of this Study

- Investigated actual casualties
- Worked with USCG Office of Investigations and Analysis (G-MOA)
- Looked at ten-year window (1991-2001)
 - Searched for “Breakaway” cases
 - Reviewed cases individually
 - 50+ Breakaways recorded due to passing vessels
 - 20+ investigated in depth; preliminary analysis and comparison to empirical mooring force analysis

USCG MC Incidents

- 1991-2001 “Breakaways”
 - 1,000’s of entries
 - 50+ cases of passing vessel breakaways

● Challenges

● Data:

MC Case	<u>Waterbody</u>	Material
Unit	River Mile	District
<u>Vsl Ind</u>	Latitude	Num <u>Vsls</u>
<u>Pers Ind</u>	Longitude	Num <u>Facs</u>
<u>Fac Ind</u>	Primary Nature	FY
<u>Pol Ind</u>	Casualty Class	Vessel Name
Incident Date	Deaths	Flag
Incident Time	Missing	Vessel Service
Subject	Injured	Damage <u>Eval</u>
Location	Total Damage	<u>Vsl</u> Operation
City	Mode	<u>Vsl</u> Status
State	Severity	

Houston-Galveston Safety Advisory Committee
Mooring Subcommittee
Moored/Passing Vessel Interaction Questionnaire

The interaction of moored and passing vessels is a recurring predicament for vessels in Houston. Ships and barges have been pulled off docks causing line breaks, hose ruptures, and other damages. In an attempt to research the history and magnitude of vessels being pulled away from their moorings, Houston-Galveston Safety Advisory Committee (HOGANSAC) has developed a questionnaire for distribution within the Houston area ports. If you have records of incidents where damages have occurred from the interaction of passing and moored vessels, HOGANSAC requests that you take the time to complete the attached questionnaire.

HOGANSAC is interested in any information that amplifies the answers that you give in the questionnaire. If your company has conducted a report or investigation regarding the incident, you are encouraged to attach it. Submitting photos or a sketch of the mooring line arrangements, including the vessel, pier, and mooring securing points used on both the vessel and pier sides, may help HOGANSAC understand the forces at work at the time of the incident. Witnesses' observations of vessel motion and line condition at the time of the incident are extremely useful. A general description of the berth's construction (open/closed face, seawall, etc) and the hydrology around it is also useful, if known.

The "Other Factors" section of the questionnaire is designed for you to add factors affecting the incident that weren't captured by the questionnaire. For instance, if an incident happened because a passing ship was forced closer than usual to the affected berth to avoid dredging operations, multiple ships passed causing increased interaction effects, or mooring fittings on the pier were inadequate for the vessel size, please include that information.

HOGANSAC will keep any information you provide confidential. If you have questions about the survey, please contact Mr. Alton Landry at (713) 678-7711. Please send the completed questionnaire and any accompanying documents to:

Marine Exchange of the West Gulf, Inc.
Attn: Mr. Alton Landry
111 East Loop North
Houston, TX 77029
Fax: (713)678-4839
E-mail: marinexchangehou@aol.com

Thank you for your time and interest in making the Houston Ship Channel a safer place to operate!

General Information

PLEASE COMPLETE ONLY THOSE ITEMS FOR WHICH YOU HAVE INFORMATION.

SEND OR FAX TO: Marine Exchange of the West Gulf, Inc.
Attn: Mr. Alton Landry - 111 East Loop North - Houston, TX 77029
Fax: 713-678-4839 - E-mail: marinexchangehou@aol.com

PLEASE REPORT ALL INCIDENTS IMMEDIATELY TO HOUSTON VESSEL TRAFFIC AT 713-671-5103, OR VIA VHF RADIO CHANNEL 5A.

Date/Time of incident: _____
Terminal name/location: _____
Nature of incident: _____
Wind conditions: _____ Tide information/current speed: _____
Depth of water along inboard length of tow/ship _____
Bow: _____ Stern: _____
Center: _____ Other depths: _____
Geography of channel in vicinity of terminal: _____
Orientation of Dock to Ship Channel: (Alongside, Perpendicular, Other) _____
Specific hydrology issues (including pier construction and bottom conditions): _____

Moored Vessel Information

Vessel name: _____
Draft at time of incident - Fore: _____ Aft: _____
Beam: _____ DWT: _____ LOA: _____
Transfer conditions (circle one): Loading Unloading No transfer
Orientation of vessel on dock: (Alongside, Stern To, Doubled Up, Single Wide): _____
Number and arrangement of lines required by vessel/facility: _____
Describe breakaway (stern pulled away from pier, upward surge, etc.): _____

Mooring line arrangement (please attach sketch, note number of lines and parts, material of construction, showing which lines parted, including angles that lines make with vertical)

Line Breakage Information (if applicable)

Parted Line location(s) (bowline, aft bow spring, etc.): _____
Length of line: _____
Number of Parts: _____
Line size/material: _____
Condition of lines: _____
Frequency of line inspections: _____
Time of last line inspection: _____
Description of line securing points used (chocks, tension winches, bitts, pilings, etc.): _____

Passing Ship Information (estimated information is acceptable)

Ship name: _____ Loaded or Empty (Circle One)
Draft: _____ LOA: _____ Beam: _____ DWT: _____ Speed: _____
Closest point of approach of passing ship to berth: _____
Ship direction (inbound/outbound): _____

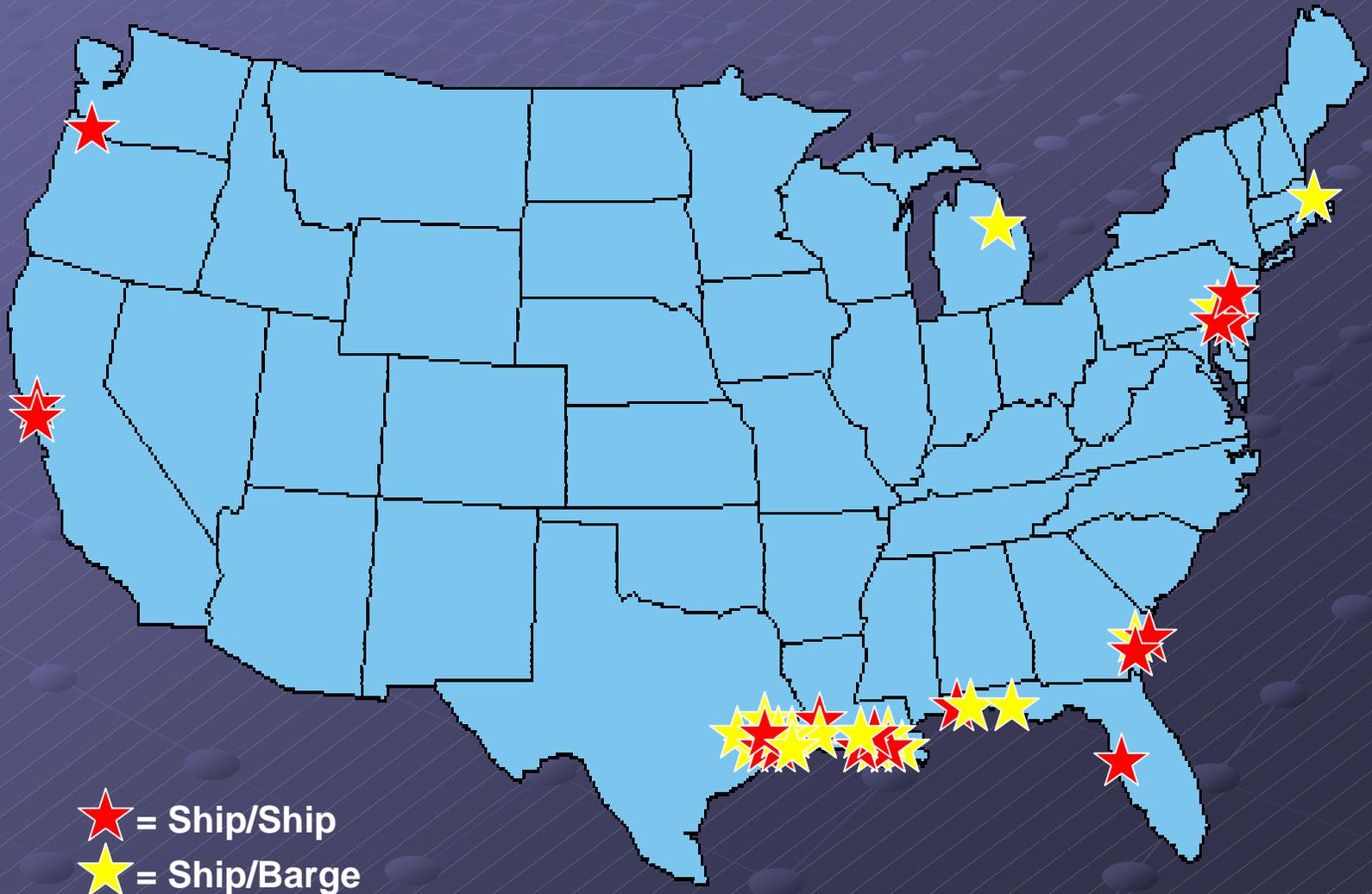
Other Factors/Events

What other factors contributed to the event? (Passing ship forced near the pier, etc.): _____

USCG MC - Breakaways

Alaska

Hawaii



★ = Ship/Ship

★ = Ship/Barge

Vessel Critical Profile (VCP)

VCP Name QUEENSLAND STAR VIN 7226275 17 Sep 2002

Vessel Critical Profile

Name/ QUEENSLAND STAR Primary VIN/ 7226275 Call/ MZBM7 Flag/ UK

Alt VIN/ 7226275 Type IMO Number

---Involved Parties---

Role	Name	Party Id
Flag State	UNITED KINGDOM	833027
Operator	P & O NEDLLOYD LTD	785792
Owner	BLUE STAR LINE LTD	288529
Classification Society	LLOYD'S REGISTER OF SHIPPING	484411

---Vessel Specifics---

Service/ Freight Ship	Gross Tons(GT ITC)/	Home/Hailing Port/ Not Documented
Propulsion/ Diesel Direct	Gross Tons(GRT)/ 25031	Date Keel Laid/ 30Apr1972
Routings	Deadweight Ton/ 27393	Date Delivered/ 22Dec1972
Ahead HorsePower/ 17100	Length/ 712.1 (ITC)/ 217	Hull Material/
Astern HorsePower/	Super Structure Color/	Hull Color/
Class/	Type/	Sub Type/

---Certificate/Document Status---

Document	Activity#	Agency	Port	Issued	Expires	Status
International Tonnage Certificate	843749	N/A	LONDON	23Feb2000		VALID
ISM - Safety Management Certificate		N/A	NONUS	21Jul1998	28Jun2003	VALID
Certificate of Compliance - Pass/Freight Vessel	1082636	USCG	PHIMS	01May1996		VALID

---PS Information---

Total/ 12					
1. Port/ SAVGA	EDA/ 03May2002	EDD/ 04May2002	Status/ Departed		
Priority #/ 0	LPC/ NORVA	NPC/			
Cargo/					
Location/					
Comments/					

VCP Name QUEENSLAND STAR VIN 7226275 17 Sep 2002

2. Port/ HOUMS	EDA/ 08May2002	EDD/ 09May2002	Status/ Departed
Priority #/ 0	LPC/ Savannah	NPC/	
Cargo/ Other Packaged Cargo			
Location/ BARBOURS CUT			
Comments/			
3. Port/ PHIMS	EDA/ 14Jul2002	EDD/ 16Jul2002	Status/ Departed
Priority #/ 0	LPC/ KNGSTN	NPC/	
Cargo/			
Location/ PAM			
Comments/ CONTAINERS/INC			
4. Port/ NORVA	EDA/ 17Jul2002	EDD/ 17Jul2002	Status/ Departed
Priority #/ 4	LPC/ PHILA	NPC/ Sav	
Cargo/			
Location/ NIT			
Comments/			
5. Port/ SAVGA	EDA/ 19Jul2002	EDD/ 19Jul2002	Status/ Departed
Priority #/ 0	LPC/ NORVA	NPC/ HOU	
Cargo/			
Location/ GARDEN CITY TER			
Comments/			
6. Port/ HOUMS	EDA/ 19Jul2002	EDD/ 19Aug2002	Status/ Departed
Priority #/ 0	LPC/ NORVA	NPC/	
Cargo/ Bulk Solid HAZMAT			
Location/			
Comments/			

---All Open Activities---

Total Open Activities/ 1

- Activity #/ 1648673 Orig Port/ SAVMS Owner Port/ SAVMS Start Dt/ 19Jul2002
Role Type/ Subject to Marine Inspection Activity Type/ Vessel Operational Control
Status/ Open - In Progress Date Status Last Changed/ 19Jul2002
Notes (Truncated)/ VESSEL REQUESTED LETTER OF DEVIATION TO ENTER PORT OF SAVANNAH WITH INOPERABLE GYRO COMPASS. REPAIRS WERE TO BE MADE IN PORT.

---All Closed Activities (W/in 18 months)---

Total Closed Activities/ 5

- Activity #/ 1646490 Orig Port/ PHIMS Owner Port/ PHIMS Start Dt/ 15Jul2002
Role Type/ Subject to Marine Inspection Activity Type/ Boarding
Activity Subtypes/ 0
Status/ Closed - Agency Action Complete Date Status Last Changed/ 15Jul2002
Notes (Truncated)/ CONDUCTED PORT SECURITY DOCKSIDE BOARDING OF M/V QUEENSLAND STAR DUE TO HIGH INTEREST VESSEL (HIV) STATUS. THIS WAS A JOINT BOARDING WITH CUSTOMS AND IMMIGRATION PERSONNEL. SWEEPS OF ENGINE ROOM, STACK, AFT STEERING, DECK, AND RANDOM CARGO HOLDS WERE MADE. NEGATIVE RESULTS.
- Activity #/ 293728 Orig Port/ PHIMS Owner Port/ PHIMS Start Dt/ 18Sep2001
Role Type/ Inspected Vessel (MISIS) Activity Type/ Vessel Inspection
Status/ Closed - Agency Action Complete Date Status Last Changed/ 21Sep2001

Vessel Critical Profile

Name/ QUEENSLAND STAR

Primary VIN/ 7226275

Call/ MZBM7

Flag/ UK

Alt VIN's

7226275

Type

IMO Number

---Involved Parties---

Role	Name	Party Id
Flag State	UNITED KINGDOM	833027
Operator	P & O NEDLLOYD LTD	785792
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---Vessel Specifics---

Service/ Freight Ship	Gross Tons(GT ITC)/	Home/Hailing Port/ Not Documented
Propulsion/ Diesel Direct	Gross Tons(GRT)/ 25031	Date Keel Laid/ 30Apr1972
Route/ :	Deadweight Ton/ 27593	Date Delivered/ 22Dec1972
Ahead HorsePower/ 17100	Length/ 712.1 (ITC)/ 217	Hull Material/
Astern HorsePower/	Super Structure Color/	Hull Color/
Class/	Type/	SubType/

---Certificate/Document Status---

Document	Activity #	Agency	Port	Issued	Expires	Status
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MC Investigation Reports

MCIR MARINE CASUALTY INVESTIGATION REPORT 25JUL02

CASE NUMBER../ MC00002633 INV INIT/ MJD PORT/ MOBMS LAST UPDATE/ 19JUN00
CASUALTY TYPE: VESSEL/ X PERSONNEL/ FACILITY/ POLLUTION/ MARPOL/
INCIDENT DATE/ 15FEB00 TIME/ 425 KNOWN/ ESTIMATED/ X REF CASE/
NOTIFY DATE../ 16FEB00 TIME/1521 REPORTER TYPE/PARTY,NEC
SUBJECT...../ M/V STAR IKEBANA; WAKING LOCAL FILE REFERENCE/
LOCATION...../ MOBILE BAY LOCAL CODE/
INCIDENT STATUS: VERIFIED/ NOT VERIFIED/ X VERIFIED, NOT REPORTABLE/
NOTIFY/ ACTION: CTF/X RETURN/ (TO IAPR)

--- VALIDATION AND ENDORSEMENT ---

	END/FWD	END/CLS	RETURN	USER-ID	NAME	DATE
INVESTIGATOR:	X			MCENERY	SUSAN MCENERY	19JUN00
UNIT COMMAND:		X		MCENERY	SUSAN MCENERY	19JUN00
DIST REQ? :						
HQ REQ? :						

--- GENERAL INFORMATION ---

CITY/	MOBILE	ST/ AL	WATERBODY/ MOBILE BAY
RIVER MILE/	.	LATITUDE/ N3-41.0	LONGITUDE/ W88-2.5
CAS SUMMARY: TYPE/	BREAKAWAY	CLASS/ NONE	
POSSIBLE DRUG INVOLVEMENT?/	N	PUBLIC VESSEL/	BOATING/
DEATHS/	MISSING/	INJURED/ TOTAL	DAMAGE/700
ENV IMPACT: MODE/	SEVERITY CATAGORY/	MATERIAL CATAGORY/	
OSC/	EPA REGION/	CLEANUP REQ?/	
RESPONSE BY NSF?/	NSF TIME TO RESPOND/	HOURS	
NOTIFICATION FROM NRC?../		NRC CASE.../	
NOTIFICATION FROM APHIS?/	N	APHIS PORT/	

--- INCIDENT BRIEF ---

M/V ANNOULA WAS TIED UP AT MCDUFFIES TERMINAL, WHEN THE M/V STAR IKEBANA HEADING SOUTHBOUND ON THE MOBILE RIVER, CAME BY AND REPORTEDLY WAKED THE M/V ANNOULA CAUSING TWO LINES TO PART. NO OTHER DAMAGE OCCURED. INCIDENT COULD NOT VERIFIED; CASE CLOSED TO FILE.

CASE NUMBER../ MC98004924 INV INIT/ MDW PORT/ NEWMS LAST UPDATE/ 05MAY98
CASUALTY TYPE: VESSEL/ X PERSONNEL/ FACILITY/ POLLUTION/ MARPOL/
INCIDENT DATE/ 09APR98 TIME/ 1830 KNOWN/ ESTIMATED/ X REF CASE/
NOTIFY DATE../ 21APR98 TIME/1300 REPORTER TYPE/RESP PARTY
SUBJECT...../ P/V DELTA QUEEN/WAKE DAMAGE LOCAL FILE REFERENCE/
LOCATION...../ ROBIN ST WHARF LOCAL CODE/
INCIDENT STATUS: VERIFIED/ NOT VERIFIED/ VERIFIED, NOT REPORTABLE/ X
NOTIFY/ ACTION: CTF/X RETURN/ (TO IAPR)

Narrative Supplement

--- VALIDATION AND ENDORSEMENT ---

END/FWD END/CLS RETURN USER-ID NAME DATE
INVESTIGATOR: X MDW CW03 MICHAEL D. WHITE 01MAY98
UNIT COMMAND: X KBP CDR KEN PARRIS
DIST REQ? :
HQ REQ? :

MCNS MARINE CASUALTY NARRATIVE SUPPLEMENT 25JUL02
CASE/ MC98004924 PORT/ NEWMS SUBJECT/ P/V DELTA QUEEN/WAKE DAMAGE DATE/ 09APR98

--- GENERAL INFORMATION ---

CITY/ NEW ORLEANS ST/ LA WATERBODY/ LOWE
RIVER MILE/ 96.0 LATITUDE/ N29-56.0 LONGITUDE/ W90-
CAS SUMMARY: TYPE/ BREAKAWAY CLASS/ NONE
POSSIBLE DRUG INVOLVEMENT?/ N PUBLIC VESSEL/
DEATHS/ MISSING/ INJURED/ TOTAL
ENV IMPACT: MODE/ SEVERITY CATAGORY/ MATERIAL CATAGO
OSC/ EPA REGION/ CLEANUP REQ?/
RESPONSE BY NSF?/ NSF TIME TO RESPOND/ HOURS
NOTIFICATION FROM NRC?../ NRC CASE.../
NOTIFICATION FROM APHIS?/ N APHIS PORT/

--- COMMENTS ---

SUBJ: WAKE DAMAGE OF THE DELTA QUEEN AT THE DOCK ON 09APR98
ON APRIL 9, 1998 AT APPROXIMATELY 1830 THE DELTA QUEEN WAS MOORED PORT SIDE TO OR HEAD DOWN AT THE ROBIN STREET WHARF. A NORTHBOUND SHIP THE AMBER WAS BEING PILOTED BY NOBRA 66, CAPTAIN D.T. WARTENBERG. THE AMBER PASSED THE DELTA QUEEN AT A REPORTED HIGH SPEED AND CLOSE ABOARD. THIS RESULTED IN THE BREAKING OF TWO MOORING LINES, SMASHING OF THE STERN GANGWAY RAMP AND BREAKING TWO SAFETY CHAINS CONNECTED TO STANTIONS ON THE DOCK. THE ROBIN STREET WHARF IS LOCATED AT MILE 96.0 OF THE MISSISSIPPI RIVER ON THE EAST BANK JUST ABOVE THE GREATER NEW ORLEANS BRIDGE. THE AMBER PASSED THE DELTA QUEEN ON HER WAY UP RIVER AND WAS REPORTEDLY GETTING READY TO MEET A DOWN BOUND BULK SHIP.
THE CARROLTON GAUGE WAS AT 13.5 FEET. THE RIVER WAS RUNNING AT AN ESTIMATED 3.5 MILES AN HOUR. TALKING WITH THE GOVERNOR NICHOLLS LIGHT OPERATOR, IT IS NOT UNCOMMON FOR SOME SHIPS TO MAKE 15 MILES PER HOUR OR MORE AGAINST THAT CURRENT. THERE IS A VESSEL THAT WORKS AT A FLEET ON ALGIERS POINT WITH VIDEO TAPE CAPABILITY. UNFORTUNATEL THE TAPE HAS BEEN ERASED. THIS MAY HAVE BEEN A WAY TO DETERMINE THE ACTUAL SPEED OF THE VESSEL.
THE DELTA QUEEN IS 51 FOOT, 61 GROSS TON, 540 HORSEPOWER, UNINSPECTED RIVER TOWBOAT OF CONVENTIONAL DESIGN.
THE AMBER IS A 89,681 GROSS TON, PANAMANIAN REGISTERED FREIGHT SHIP BUILT 31DEC73. COMMUNICATIONS, WEATHER AND FATIGUE ARE NOT FACTORS IN THIS CASE.
THE APPARENT CAUSE WAS A COMBINATION OF EXCESSIVE SPEED AND CLOSE PROXIMITY ON THE PART OF THE FREIGHT SHIP AMBER IN RELATION TO THE DELTA QUEEN. A CONTRIBUTING FACTOR MAY BE THE HIGH RIVER STAGE. A SECOND CONTRIBUTING FACTOR MAYBE THE MEETING OF THE DOWN BOUND SHIP. THIS CASE WILL BE ATTACHED TO THE PILOTS IPN FOR FUTURE REFERENCE. CASE CLOSED.

--- INCIDENT BRIEF ---

SEE MCNS FOR DETAILS.

--- ACTIONS REPORTED ---

CASE SUPPLEMENTS

WITNESS LIST.....(IAWL)/X
COMDT RECOMMENDATION.(MCCR)/
CASUALTY DETAILS.....(MCDD)/
NARRATIVE SUPPLEMENT.(MCNS)/X
REB ACTION RECOMMEND(MCRA)/

Analysis of Cases

- Used PASS-MOOR (Seelig, 2001)
 - Simple, requires little input parameters
 - Still required to infer several characteristics
 - Ship
 - Channel
 - Mooring
- Sensitivity Analysis
- Other tools reviewed/employed for conditions outside range of PASS-MOOR



Technical Report
TR-6027-OCN

PASSING SHIP EFFECTS ON MOORED SHIPS

by
William N. Seelig, P.E.

NFESC East Coast Detachment
Washington Navy Yard
1435 10TH STREET SE Suite 3000
Washington Navy Yard DC 20374-5063

20 November 2001

Prepared for:

Commander, Naval Facilities Engineering Command
Engineering Innovation & Criteria Office

Distribution is unlimited.

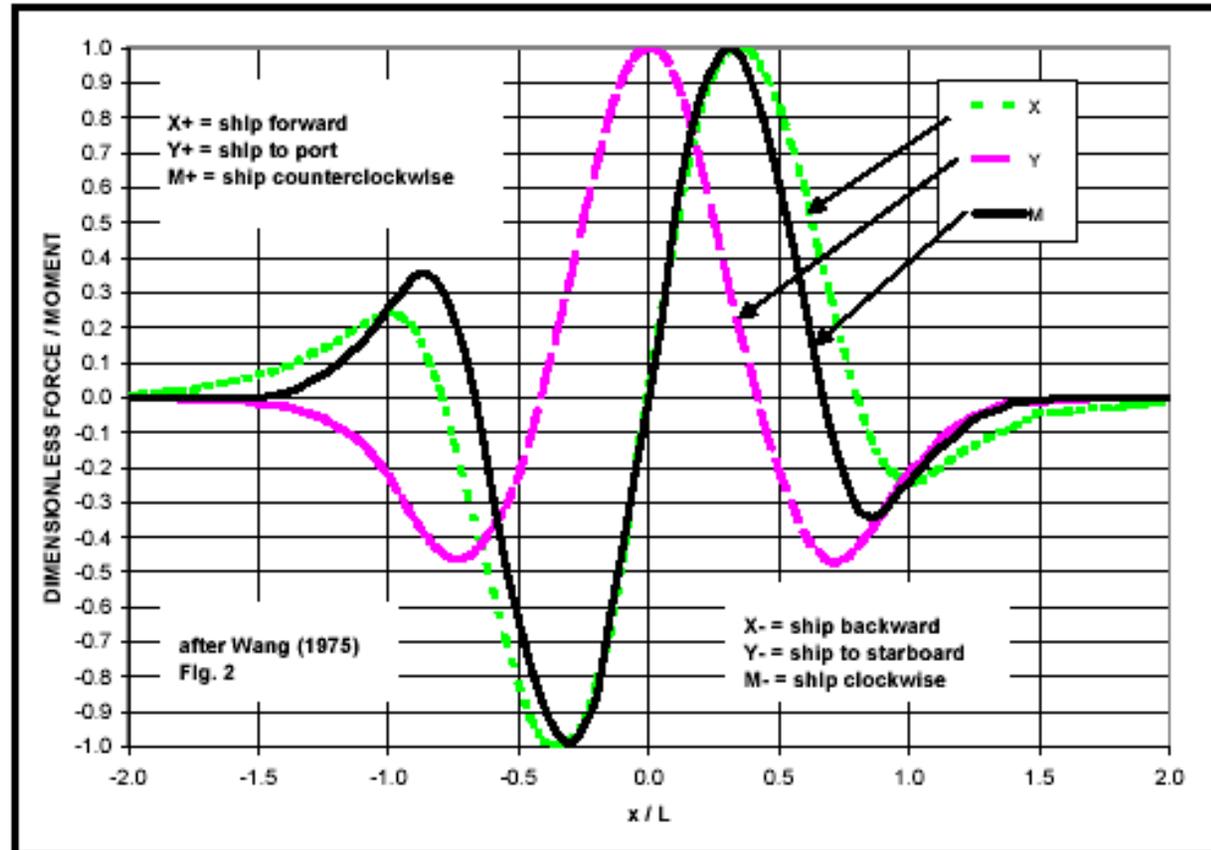


Figure 2.1-1 DIMENSIONLESS PASSING SHIP FORCING
ON MOORED SHIPS FOR DEEP WATER
(after Wang, 1975)

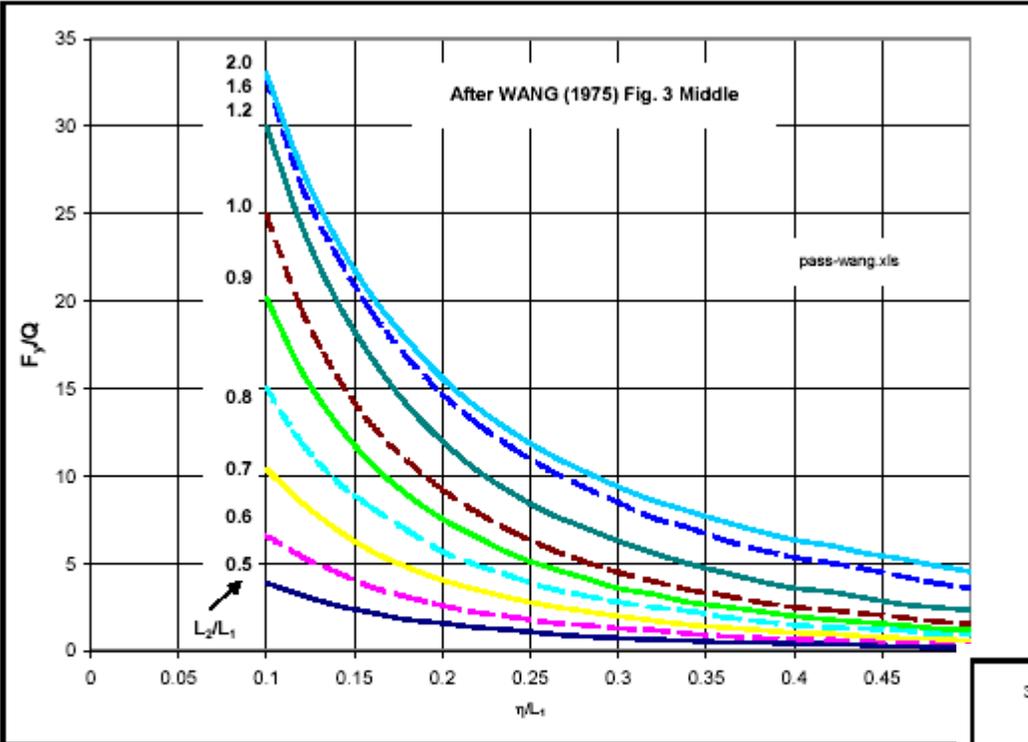


Figure 2.1-7. NON-DIMENSIONAL PEAK FORCE IN THE SWAY DIRECTION ON THE MOORED SHIP (after Wang, 1975) FOR DEEPWATER

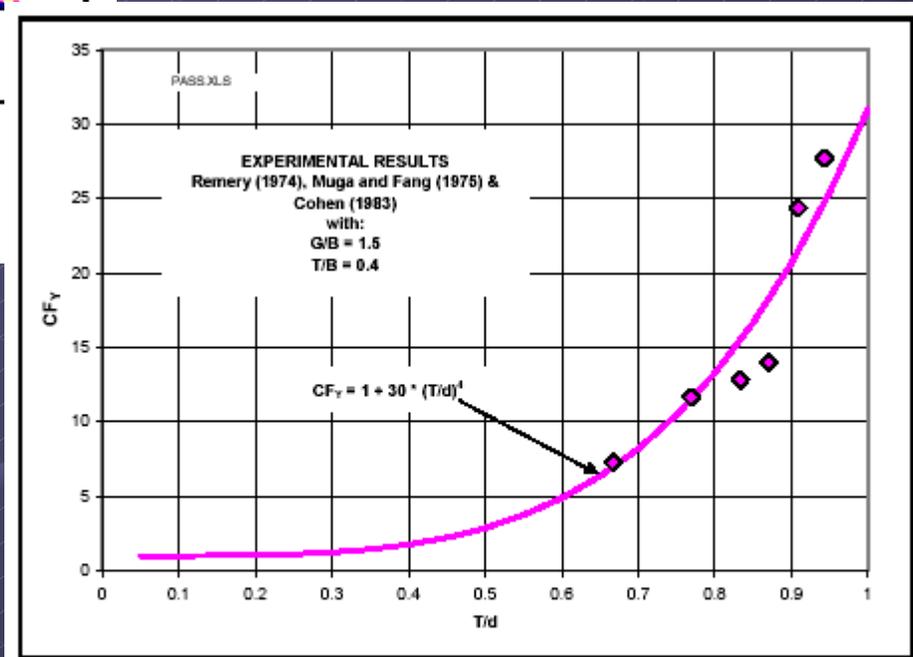
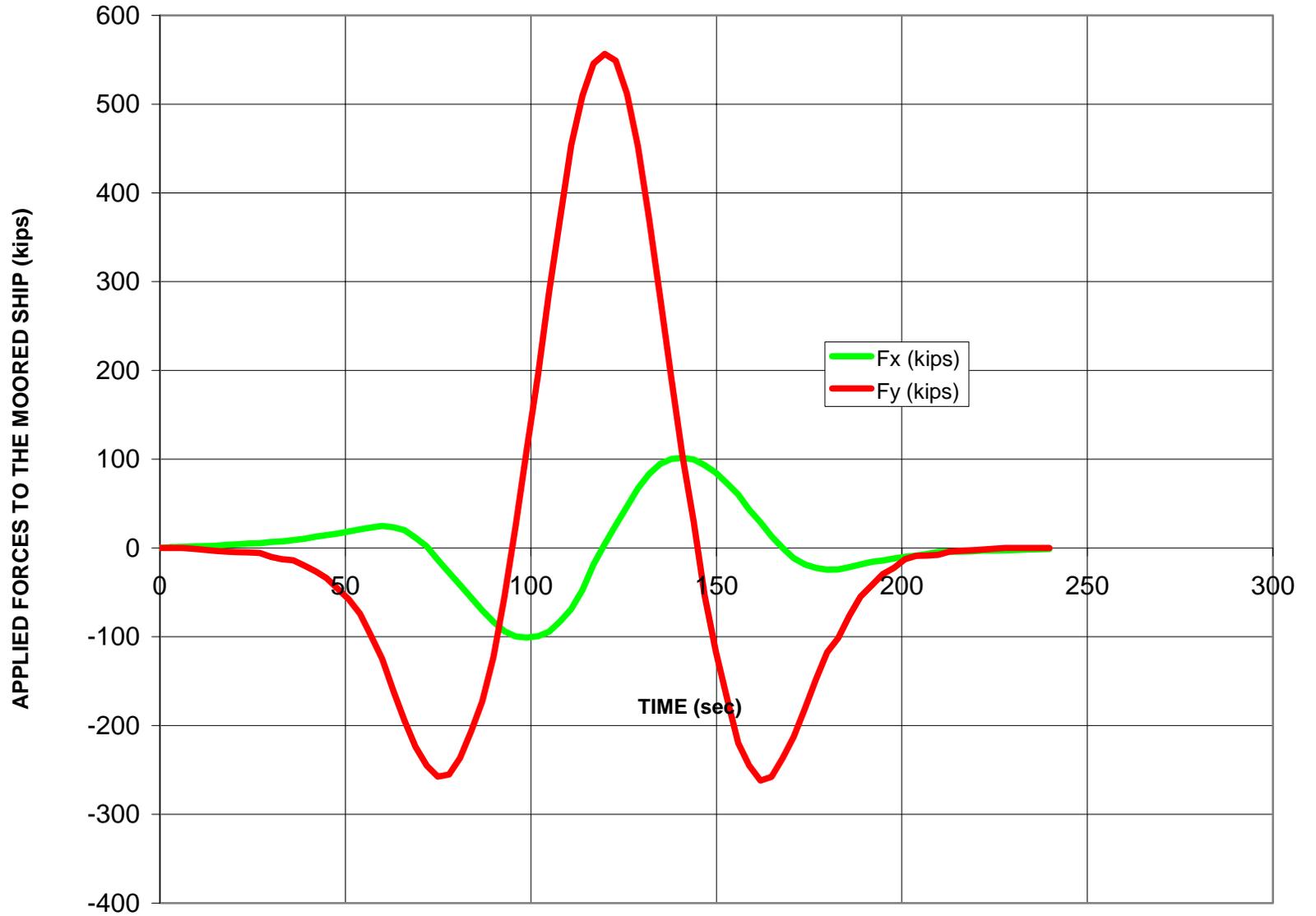
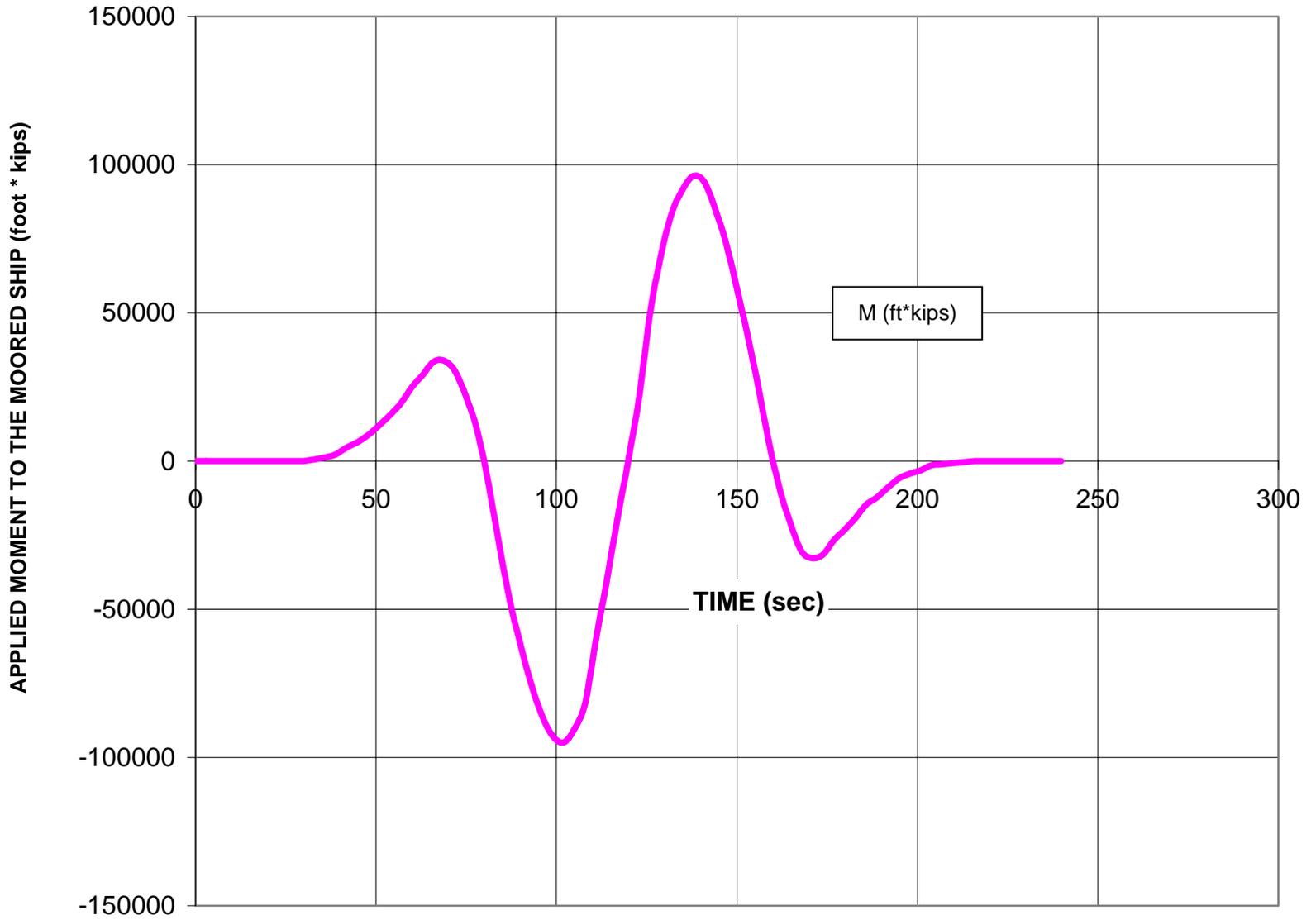


Figure 2.2-2. SAMPLE SHALLOW WATER CORRECTION FACTOR FOR THE PEAK SWAY FORCE





Findings

- Usually larger vessel passing smaller
- In most cases, estimated forces from empirical analysis methods were much smaller than required for line breakage
 - Other factors attributable to breakage occurrence?
 - A few cases did indicate excessive line forces
- Results are highly dependent on
 - Vessel Velocity
 - Vessel Proximity
 - Current velocity
 - Channel and berth depths

Additional Factors

● Slack Lines

- Snap-Loading
- May Increase Line Load by an order of magnitude
- Lean and Price (1977), Remery (1974)

● Underkeel Clearance (UKC)

- May Increase Added Mass values by factor of 2.0

● Shoaling of Channels / Channel Sides / Quays

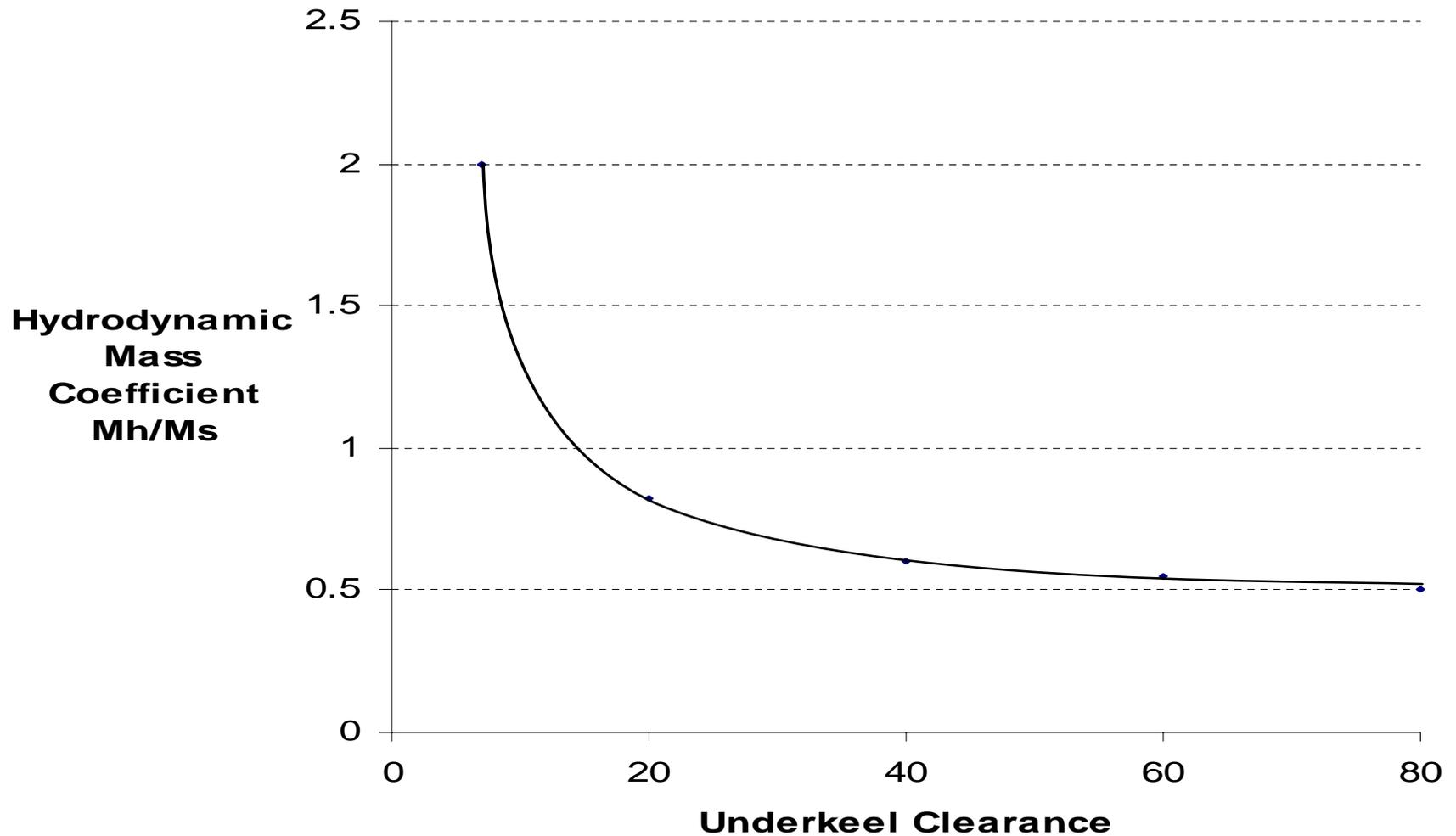
- Directly Affects UKC
- Also Impacts Hydrodynamics

Slack Mooring Lines and Snap Loading

- “Slack Mooring Lines” were directly implicated in many of the cases studied
- Snap loading arises when a mooring line transitions suddenly from a slack condition to a taut condition
- May result in significantly greater force
- See, e.g.
 - Farmer, A. (1999), “Investigation Into Snap Loading of Cables Used In Moored Breakwaters,” VTech thesis.
 - Huang, S. and Vassalos, D. (1993). “A numerical method for predicting snap loading of marine cables.” Applied Ocean Research, Vol. 15, pp. 235-242.
 - Huang, S. and Vassalos, D. (1995). “Analysis of taut-slack marine cable dynamics.” OMAE 1995, Vol. I-B, ASME, New York, pp. 401-406.
 - Niedzwecki, J.M. and Thampi, S.K. (1991). “Snap loading of marine cable systems.” Applied Ocean Research, Vol. 13, pp. 2-11.

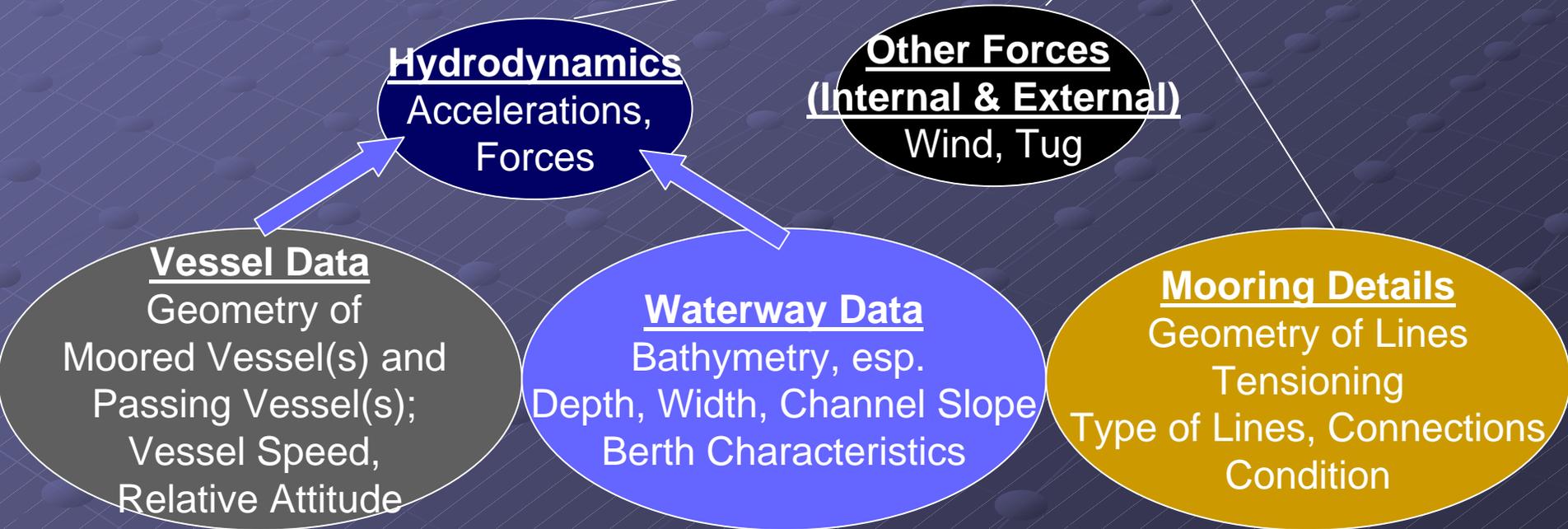
Model Ship in Translation Under Constant Pulling Force

after NATO, "Analytical Treatment of Problems of Berthing & Mooring Ships," 1971



Discussion

Mooring Breakaway



Conclusions

- Frequency of mooring breakaways due to passing vessels is significant
 - Reporting issues
 - Several per year (conservative)
- Mooring analysis methods
 - [Conventional] Environmental
 - Ship-Ship
 - Coupled effects
- Mooring force & response dynamics
- Limiting factors?



OIL COMPANIES INTERNATIONAL MARINE FORUM

**POTENTIAL HAZARDS ASSOCIATED
WITH REQUESTS FOR ADDITIONAL
MOORING LINES BY TERMINAL
OPERATORS**

September 1997

The OCIMF mission is to be recognised internationally as the foremost authority on the safe and environmentally responsible operation of oil tankers and terminals.

The Oil Companies International Marine Forum (OCIMF) is a voluntary association of oil companies having an interest in the shipment and handling of crude oil and oil products. OCIMF is organised to represent its members before, and consult with, the International Maritime Organization (IMO) and other government bodies on matters relating to the shipment and handling of crude oil and oil products, including marine pollution and safety.

Selected Recommendations for Additional Work

- Slack Lines
 - Pierside Breakaway Dynamics
 - Pretensioning Technology
 - Alternative Mooring Designs
- Passing Vessel Effects on Vessels Moored not parallel to sailing line
 - More complex issue
 - Potential for higher forces & moments
- Impact of quay/pier construction and geometry
 - UKC effects
 - Hydrodynamics alongside [pierside of] vessel

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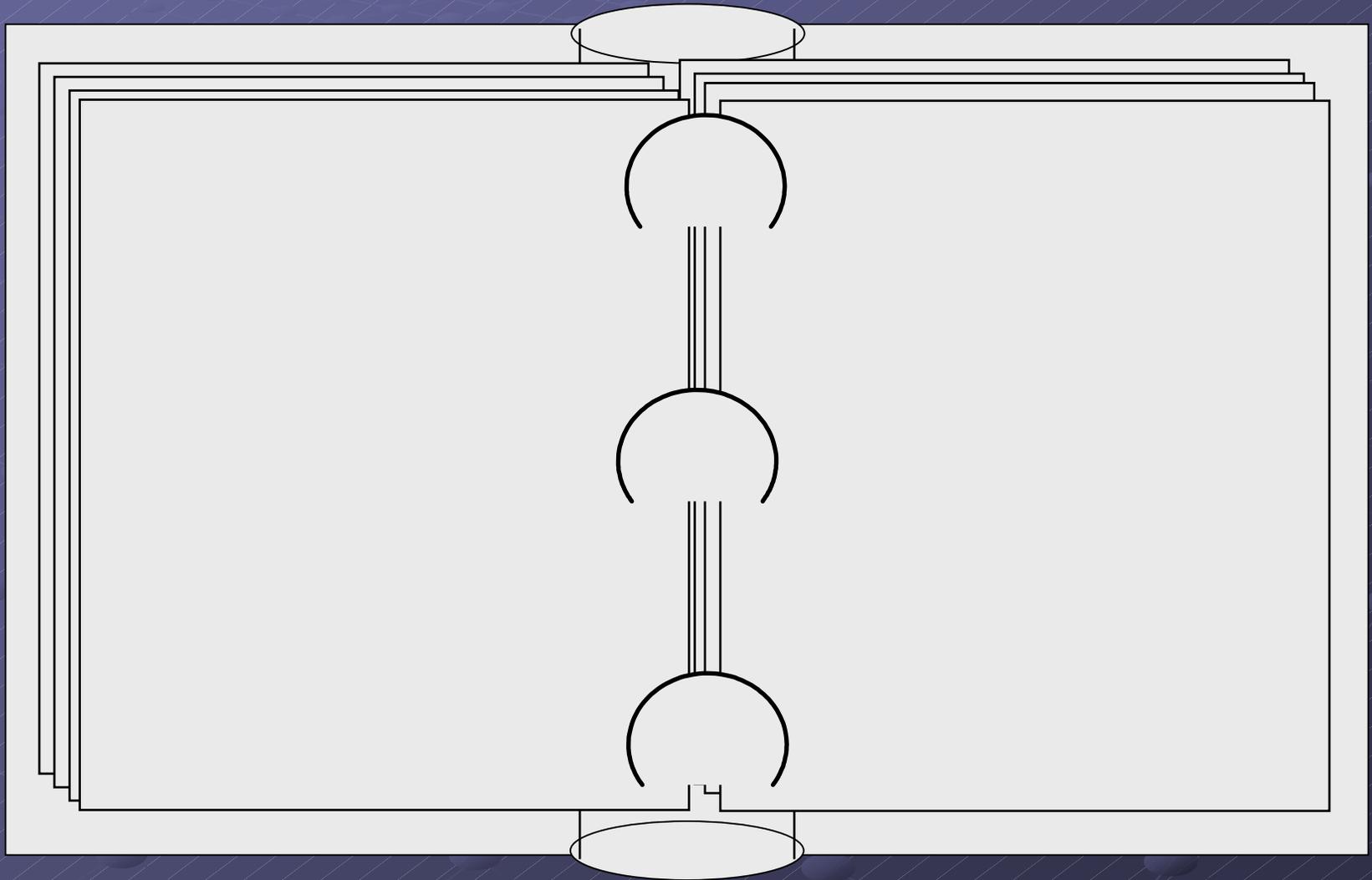


Thank You ... *Questions / Discussion?*



Sovereign Maersk's Stern Mooring Lines
(Photo: World Shipping Council)

Interesting Cases from the Files ...



● **MCNSMARINE CASUALTY NARRATIVE SUPPLEMENT 24 JUL 02 CASE/**
MC94005510PORT/ NEWMSSUBJECT/ TOPAZ - CELILIA B. SLATTEN DATE/
16MAR94

● **--- COMMENTS ---**16MAR94,0330/Welcome, LA: M/V TOPAZ broke loose from its moorings at Zen-Noh grain elevator and struck the ACBL Welcome Fleet. Statements from Zen-Noh stevedores, revealed that at 0130, the vessel's springlines were observed releasing and the vessel moving fore and aft as well as away from the dock. At 0215, the vessel's forward breast line parted. Stevedores tied a loop on the severed line and replaced the line on the dock's bollard, but noticed the ship's crew never took up the slack in the line, thus rendering the line ineffective. The vessel continued to work away from the dock. At 0245, TOPAZ requested the assistance of harbor tugs. The first tug arrived at 0300, after the vessel had broken away from the dock. The tugs appeared to move the ship's stern toward the dock, apparently causing the ship's bow to head out into the river several hundred feet. Four broken lines were found by Zen-Noh personnel. The remainder of the lines appeared to have spun off of their winches, since they were long and had no broken ends. Even the intact lines had splices. The vessel "warped" away from the dock until it was abreast the current. The vessel travelled downriver, not under command until it struck the ACBL Welcome barge fleet. Two assist tugs were damaged in the allision. At some point, the vessel dropped its port anchor. Whether the starboard anchor was released is unclear since statements conflict on this point. Only the port anchor was released when we arrived on scene. The gangway to the vessel, belonging to Zen-Noh, was smashed between the side of the ship and the dock. The dock sustained some broken wooden whalers on the dock structure. The anchor had dropped near a group of four natural gas pipelines. **THIS ACTION PRESENTED A CONSIDERABLE HAZARD TO THE PORT.** When I arrived on scene, the ship was stemming the current with a pilot in charge of the deck. I issued orders on behalf of the COTP to cut the rode to remove the danger of a potential natural gas release and explosion. I ordered the vessel to anchor or moor at the nearest safest anchorage or mooring. After cutting the anchor chain, the vessel anchored in Burnside Anchorage to await the return of its lines. LTJG T. J. SHOENFELT Investigating Officer

● **MCNSMARINE CASUALTY NARRATIVE SUPPLEMENT 25 JUL 02 CASE/ MC99002740 PORT/
NEWMSSUBJECT/ LUCY FLEET/BREAKAWAY DATE/ 12 FEB 99**

● **--- COMMENTS ---** Subject: The Barge Breakaway at Lucy Fleet on February 12, 1999. At approximately 0300 hours on February 12, 1999, the Tug Southern Star was conducting a routine fleeting operation at Lucy Fleet. He noticed that tier eleven was missing and informed the Lucy Fleet Tug Woody Dumas. The Woody Dumas determined that eight barges had broken away from Lucy Fleet. The Woody Dumas immediately notified river traffic of this incident and specifically alerted CGB Laplace. CGB Laplace is the next fleet down river from Lucy Fleet. At approximately 0300 the dispatcher of Triangle Fleet contacted the dispatcher for CGB Laplace fleet. He notified CGB that eight barges had broken loose from the fleet and were probably headed his way. The CGB dispatcher looked up river and saw the NAV lights on a couple of light boats up river headed his way. He did not see the barges yet but notified his fleet boats. The CGB fleet dispatcher made a general broadcast to his fleet boats about the breakaway. One of the CGB fleet boats (Miss Linda) was working barges at the wash dock. The wash dock is adjacent to the number one tier of CGB Fleet. The deckhands on the Miss Linda did not see the barges but heard a series of large crashes in the area of the #1 tier. They then observed running lights from several light boats coming down river. At the same time they observed the #1 tier at CGB drift out into the river. The eight barges that broke away from Triangle are OR1231, OR6242, LTD117, LTD 106, PC107, PMC9305, MEM2175 and MEM5114. After the collision with the barges from triangle fleet, tier #1 of CGB drifted down river colliding and breaking away the entirety of tiers #4 and #5. Over 230 barges were tied up in the fleet at CGB during the collision. **It is estimated that 185 of these barges broke away, 88 empty barges and 97 loaded barges.** CGB Laplace fleet reports all barges accounted for. 104 barges have received damage. One barge, the ET-414 sunk in the middle of the river at mile 120.6 just above Shell Norco. Several barges from the barge breakaway allided with and caused damage to the forepeak and starboard #1 Wing Void of the T/S Kriti Amber while moored at the Union Carbide dock located in Taft, Louisiana. A surveyor from the vessel's class society attended the vessel with Coast Guard Marine Inspectors. The cargo was offloaded and repairs made for the vessel to departing port. Case PS99017365. The MEM 5114 was the barge moored to the spud barge in tier eleven at Triangle Fleet. Pictures of the cable on this barge show a steel cable broken just below (less than a foot) the clamp used to form an eye in the cable. In the picture the eye is still around the bit of the barge MEM 5114. This barge is believed to have been the initial domino causing the break away. Fleet records/log indicate that the moorings were checked the previous evening at 1700 by an experienced hand. This Marine Casualty was not a major marine casualty in itself but a series of minor collisions or casualties that when grouped together become a Significant Marine Casualty in dollar amount. Human error, The RNA, communications and fatigue were not factors in this case. There was no pollution or injuries. The apparent cause of the casualty was equipment failure. The cable on the MEM 5114 parted starting a domino effect of barges going down the river. There is no regulation for these cables. They are usually cables that have served in another capacity such as on a crane. Once they are past the allowed service they are replaced and put to use in the fleets. A contributing factor may have been the high water of the river and a storm passing the area during the night. There are indications that a ship passed the fleet an hour before the breakaway. The surge caused by the vessel may have also been a factor. This would not be a cause because ships pass the fleet several times in a 24-hour period and should be able to stand up to the strain on the cable. Neither a 2692 nor a surveyors report has been received from the T/S Kriti Amber damaged by the barges at TAFT. The ship lawyers have been contacted with negative results. Once obtained a separate case will be opened and attached to this case. Case Closed. M.D. White, CWO4